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Preventing Pandemics: Contributing Factors to Susceptibility During the H1N1 Pandemic

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Contributing Factors to Susceptibility

During the H1N1 Pandemic

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Abstract

This paper uses Poisson and ordinary least squares (OLS) regression techniques on panel data from the United Nations World Health Organization's FluNet to evaluate factors contributing to a country's H1N1 influenza (swine flu) pandemic outcomes. Countries with higher development (as measured by gross domestic product and the United Nations Human Development Program's development index) and higher mean annual temperature (as measured in the capital city) tended to have an earlier first reporting of cases. Though subject to reporting biases, the results also suggest that mass vaccinations have a negative effect on weekly reported cases. Countries that would vaccinate in the future (after the vaccine was developed) had on average six times the weekly case reports of countries that wouldn't vaccinate. Other policies tested (thermal scanners at entry points, flight bans, and pork bans) showed no consistent negative result.

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Preface

In the fall of 2010, I spent the semester studying in London. Over the summer, I had heard about “swine flu” and had even seen a few reports of it locally. Once I arrived in London, I was surrounded by National Health Service advertisements to “Catch It, Bin It, Kill It.” One of my flatmates was diagnosed with H1N1, and all of us came down with some form of it. Our school handed out hand sanitizer; our landlord came through with sanitizing wipes, twice-weekly cleanings, and extra tissues. Yet when I returned to the U.S. in the spring, I heard little of the virus. Syracuse University offered the vaccine once it was available, and had installed hand sanitizer dispensers across campus, but outside of our campus bubble, there was little apparent campaigning against the virus. I was intrigued by these regional differences, and was eager to learn more about the variation in pandemic approaches.

Dr. Christopher Rohlfs of the Economics Department helped me develop my interest in the 2009 H1N1 pandemic into a researchable question—how did countries attempt to prevent, contain, and treat H1N1, and what factors influenced their pandemic experience?

Acknowledgements

I am incredibly grateful to Dr. Christopher Rohlfs for his help in refining my thesis idea, and continued direction in developing a feasible model, providing encouragement and the faith that even I didn't have at times. Thanks are also due to Professor Jerry Kelly, my Honors Reader and undergraduate advisor, for many, many hours of counseling and advice. I'd also like to thank the entire Honors Program for being supportive throughout my education at Syracuse, and the wonderful staff of the Economics Department for taking every opportunity to enrich students' education. Thanks also to my parents and friends for putting up with me through this process…I couldn't have done this without your help.

Advice

For an Honors student, completing a Capstone seems the logical step senior year. But in reality, it should start so much earlier than that. Theoretically, I started working on my Capstone when I took econometrics my sophomore year, because the use of STATA has been invaluable to the many iterations of my project. Learning how to use the "tools of the trade" should definitely begin before your Capstone—I wish I had also learned GIS, but by senior year, it was too late. A few bits of advice, so you don't repeat my mistakes:

- Choose a topic you love. This will be at least six credits' worth of your time senior year—you want to enjoy it.
- Find the experts in your topic, and talk to them early on. If your thesis is multidisciplinary, it's helpful to have to talk it over with people from multiple departments, as they can bring different perspectives to the table.
- Do your best to make the inevitable catastrophic problem happen during your first semester…or else you'll end up working on your Capstone during spring break.
- When the inevitable catastrophic problem happens, don't lose hope. You've put several months' worth of work into this, and there's still a project there. You just need to find it.
- Reward yourself! It's a lot of work, but definitely worth the effort. Milestones give you a sense of accomplishment, and finishing is the best of all.

I. Introduction

Dr. John Snow is often lauded as one of the founding fathers of epidemiology. Dr. Snow traced cholera through London's water supply, and was able to pinpoint the pump spreading the disease. Since his time, government officials and scientists have tried to protect society from disease, focusing on identifying threats, containing them, calculating a response, and preventing future outbreaks. The H1N1 pandemic is now in the final stage of this process, with the vaccine being incorporated into the seasonal flu vaccine.

However, little research has been conducted on the different pandemic experiences of infected nations, and the effectiveness of the policies implemented during the pandemic. While some analysis of pandemic preparedness plans has been performed ("HHS…," "National…") few studies have evaluated the treatment effects of pandemic interventions. In 2009, during the height of the pandemic, the World Bank announced that global pandemics like the H1N1 pandemic can shave off up to 1% of an affected nation's GDP, making pandemic preparedness of paramount importance ("The cost…"). Oxford Economics estimated in 2009 that the pandemic would cause the world GDP to be cut by approximately 2.5 trillion dollars ("Impact of…").

Yet H1N1 fell short of predictions. As illustrated in Table 1, the pandemic caused approximately 14,300 recorded deaths around the world, compared to one million in the H3N2 pandemic in 1968-9, and two million in the H2N2 pandemic in 1956-8. H1N1 did surpass the 2003 Severe Acute Respiratory Syndrome (SARS) pandemic, which caused 916 deaths. However, the pandemic still caused economic woes from decreased productivity in the workplace, air travel effects, and impacts on agricultural trade.

Dame Deirdre Hine believes that though the pandemic prevention techniques employed were based upon more dire estimates, the preparation is worthwhile for its applicability in other pandemic situations (Hine). Hine estimates that the United Kingdom spent 1.2 billion pounds (about two billion dollars) on pandemic preparedness and response, including vaccines, antiviral drugs, communications, and stockpiling for future pandemics. Slightly less than half of this amount was spent on responding to the 2009 H1N1 pandemic specifically. ABC News estimates a much lower cost of response in Australia, approximately 200 million dollars ("$200…). The United States Congress appropriated nearly eight billion dollars to combat the pandemic, including the cost of preparedness planning for government and school officials (Amico).

There is a wide range of policies available to a government hoping to contain a pandemic, ranging from the cancellation of social events to the imposition of martial law. This paper will focus on four such policies: restricting the import of pork from nations reporting H1N1, restricting flights to and from infected nations, using infrared scanning to determine elevated body temperatures of those entering a nation, and vaccinating the population of a nation.

Of the 88 nations included in this study (selected for the presence of H1N1 and consistent availability of baseline data), 11 imposed restrictions on the import of pork, 19 restricted air travel, 34 used infrared scanning, and to date, 55 nations have implemented mass-vaccination campaigns.

This paper uses both Poisson and multiple regression modeling to estimate the impact of each policy, in combination with the other three policies and with baseline controls for demographics, time trends, and a country's previously demonstrated susceptibility to influenza. A time series analysis, looking at the pattern of new cases before and after each policy is enacted, and a binary analysis, looking at new cases once the policy is in effect, are both included in the model.

Initial findings suggest that vaccination has a reductive effect on weekly H1N1 cases in both OLS and Poisson models. Vaccination timing varied among nations, with the most developed countries vaccination in early November of 2009, and less developed countries vaccinating by January of 2010. Thermal scanning, pork bans, and flight bans were implemented by the spring of 2009, but these policies have no reductive effects in the preferred specification of the OLS and Poisson models. Countries in warmer climates, with more tourism, and with higher populations tended to have more weekly cases of H1N1. Countries with higher levels of development and tourism also tended to have an earlier start to the pandemic. Comparing the pandemic and post-pandemic periods (using the August 10th date announced by WHO), most subgroups experienced a 60% decline in weekly cases. However, North America and South America experienced much steeper declines in weekly cases, while European countries maintained caseloads only slightly decreased from pandemic levels.

This paper is divided into five sections. Following this introduction is a description of the key factors and data, and then the estimation strategies in Section III. Section IV details the results of each model, and Section V concludes.

II. Key Factors

Subtype A H1N1 influenza, or "swine flu," is a form of viral respiratory illness traditionally found in pigs and pig farmers. In general, the strain endemic to pigs cannot be transmitted by human-to-human contact. However, in April of 2009, a strain of H1N1 influenza capable of human-to-human transmission emerged in Mexico. Infections with the same viral sequence were then found in San Diego, California and Guadalupe County, Texas, and the pandemic spread to the rest of the United States and Canada (CDC briefing) (Panel A of Figure 1).

The virus spread next to the United Kingdom and parts of Asia, and by late May it had reached South America, most of Europe, Australia, and one country in Africa. By September 2009, countries in North and South America were seeing significant death tolls (more than 100), and Western Africa was among the few remaining regions without reported cases (Panel B of Figure 1). That month, the H1N1 vaccine finished development and October of 2009 saw mass vaccinations in many countries.

By the end of January 2010, death tolls in Europe and Asia had also climbed, and almost all countries in Africa had reported cases of H1N1 (Panel C of Figure 1). On August 10, 2010, the World Health Organization (WHO) declared an end to the official H1N1 pandemic, stating that they expected to see H1N1 circulate like a seasonal influenza strain. WHO also cited "herd immunity" from widespread infection and vaccination as reason for the decline in virus activity (WHO August PR). Indeed, little change in total deaths and new infections is seen between Panels C and D of Figure 1.

When news of the virus in Mexico and the United States first emerged, some nations chose to ban imports of pork and pork products from these or all nations. However, there is no scientific connection between consumption of pork and infection with H1N1. The virus is believed to be transmitted in the same way as other influenza viruses—by direct contact with respiratory droplets from coughing or sneezing (BBC Q&A). Countries enacting this policy did so within the first month of the virus's emergence.

Some nations chose to ban air travel to and from countries reporting H1N1 infections. Research by the Children's Hospital Boston suggests that air travel restrictions may be effective in delaying the regular influenza season ("A public health…"). Countries choosing this policy also enacted it within the first month of the virus's emergence.

Some nations installed thermal imaging cameras at major travel checkpoints (airports, seaports, etc). Thermal imaging cameras use infrared technology to monitor the body temperature of groups of people entering a checkpoint. Those with temperatures above the regional norm are pulled aside for additional monitoring, as an elevated body temperature suggests fever, a symptom of influenza. Countries using thermal imaging implemented the system by the second month of the pandemic.

Once the vaccine was developed, some nations implemented mass vaccination campaigns to provide the vaccine to their citizens. While some nations vaccinated "priority" groups first, such as health care workers, the dates used in this paper are those for the general vaccination open to the entire public.

However, this paper discusses the provision of vaccines only—as detailed vaccination rates were not available, this paper tests the effects of making vaccines available, rather than their use. The vaccine was not developed until September of 2009, and some nations did not conduct vaccination campaigns until February of 2010.

III. Data Description

Two main dependent variables are used in this paper—weekly H1N1 case totals as reported to the United Nations through the World Health Organization's FluNet program, and the start week of the pandemic for each country, designated by the first week in which H1N1 cases were reported through FluNet.

Country-specific characteristics are also included in the dataset, accounting for demographic, geographic, and epidemiological factors. Demographic data include each country's population, gross domestic product, annual international visitors, and development ranking by the United Nations Development Program. Dummy variables for each country's continent are also included to account for regional interaction. To adjust for baseline cultural differences influencing general disease susceptibility (social kissing, personal distance, etc), total annual seasonal influenza cases are also included. As these data are reported to the United Nations FluNet, they are presumably subject to the same reporting biases as the H1N1 pandemic data.

Four policies are also included in the data set—the use of thermal scanners at entry points, the ban of flights to and from infected nations, the ban on pork imports, and the disbursement of the vaccine developed in the fall of 2010. Using news articles and government releases, I determined which of the four policies had been implemented, and on what date they began to affect the general public.

There are 88 countries in the final data set, with weekly case reports for 110 weeks, from 2009 to 2011. Missing data reports brings the total number of country-week observations to 8,144.

Table 2 gives sample means for selected data variables. The weighted column details the means of data observations, which is equivalent to weighting country means by their number of observations. The un-weighted column gives country means. The difference in these means suggests bias on the proportion of observations recorded.

The mean weekly total of new H1N1 cases for country-weeks in the dataset is 129, with a standard deviation of 553. The mean population (weighted by number of observations) of countries in the dataset is 93 million, and the mean gross domestic product (again weighted) is 70.6.

Thirteen percent of the observations in the dataset are from Africa, 22% are from Asia, 36% are from Europe, 15% are from North America, and 11% are from South America. The remaining 4% are located in Oceania. Roughly 33% of the observations are from countries considered "very highly developed," 28% are considered "highly developed," and 36% are considered to be of "medium development."

The data set has an overrepresentation of more economically developed, more populous countries, as the weighted means for these categories exceed the unweighted. Unfortunately, data are not consistently available for less populous and less developed countries. Furthermore, 27% of countries in the dataset are in Asia, but only 22% of observations. There is an overrepresentation of countries in Europe and North America, suggesting that there was more consistent data reporting in these regions. These biases limit the conclusions that can be drawn from this analysis.

In general, the warmer countries in the sample tended to have fewer weekly cases than cooler countries, consistent within subgroups of similar tourism and also within subgroups by pandemic policy selection (Tables 3 and 4). Countries choosing to ban flights to Mexico or to ban pork had a similar level of average weekly cases, between 144 and 149 new cases of H1N1 per week. Countries vaccinating or using thermal scanners had a somewhat lower average weekly caseload, between 124 and 129 new cases of H1N1 per week. More tourism also correlates with a higher average weekly caseload, both overall and within temperature subgroups.

As seen in Table 5, increases in population or tourism have a corresponding increase in average weekly new cases, as does the combination of the two factors (with the exception of the most populous, lowest tourism countries which have a lower weekly caseload than median population, lowest tourism countries). However, the interaction of temperature and population is less exact—for a given population level, countries with median temperatures have the highest weekly caseload, followed by the coldest and then the warmest. For a given temperature level, countries with median populations generally had the lowest weekly caseload, followed by those with the smallest populations, and then by the most populous countries (Table 6).

IV. Estimation Strategy

The level of observation in this paper is each country i in each week t combining to form the unit country-week. The country data set includes 88 countries from six continents, with a variety of social, cultural, and economic backgrounds. The sample was selected for consistent tracking of data, range of treatments, and a documented presence of H1N1. The data set tracks new Pandemic H1N1 Influenza cases in these countries over a period of approximately two years, from the spring of 2009 to the winter of 2011. Cases are those reported to the United Nations World Health Organization (WHO) and may represent an underestimate of total cases. However, I assume that this underreporting is relatively consistent across nations and weeks, and any country-correlated variations in reporting are adjusted for by the inclusion of seasonal influenza (Influenza A and B) data (also reported to WHO).

This paper assumes that new H1N1 influenza cases in each country-week are a function of observable baseline characteristics, known policy measures, and unobservable characteristics, first represented in a linear model as:

$$Cases_{it} = \alpha + \beta_1 X_{it} + \beta_2 Treatment_{it} + \beta_3 LagCases_{it} + v_{it}$$

The baseline characteristics included are country-specific, and address a range of social, cultural, and economic factors that would likely influence the progress of an influenza pandemic within its borders. These characteristics include the World Development Index ranking, population, seasonal influenza cases (A & B), geographic location, and overall climate.

Because of the event-probability nature of the data, this paper also includes two Poisson models—one structured specifically for panel data, and one structured as a regular Poisson model with robust standard errors. The Poisson models use the same set of variables as the OLS model with the exception of country fixed effects, as the model failed to converge with country fixed effects included. Therefore the preferred specification suggests that the count of cases in a given country i in a given week t is a function of a vector of baseline characteristics for each country i, a vector of the time trend for each week t (week fixed effects) and a vector of policy interventions with an associated country and week of implementation. While the dispersion of the data may not perfectly fit the Poisson model of equivalent conditional means and standard deviations, the use of counts as an outcome variable makes the Poisson probability model appropriate.

The treatments tested in this model are all preventative and containment treatments, not palliative or curative. When H1N1 was first detected in Mexico, 19 countries in the sample chose to restrict flights to and from Mexico (some also restricted travel to and from the U.S.). Thirty-four nations in the sample installed thermal scanning machines in their airports, monitoring human body temperature with infrared technology. Fifty-five nations in the sample disbursed the H1N1 vaccine developed in September of 2009, though some nations started vaccination campaigns later in the pandemic. Lastly, eleven nations chose to ban the import of all pigs and pork from nations where H1N1 had been confirmed. Each treatment in each country has an associated implementation date, and lags for each treatment are included to capture any delay in the policy's effect.

V. Results

I. Origins of the 2009 H1N1 Pandemic

As seen in Figure 2, there is no clear pattern between development (measured by the United Nations Human Development Program rating) and the start date of the pandemic by continent.

One might assume that the development of a country is actually a proxy for international inflows like tourism, but a comparison with continent and tourism interactions shows a relationship between high tourism and earlier start dates, suggesting something endogenous to development or tourism is the true cause (Figure 3). As Figure 4 shows, countries with higher development ratings and higher tourism tended to have an earlier start date, consistent for countries of high and median tourism. For countries with low tourism, however, there seems to be no relationship between levels of development and start date. This supports the theory that tourism was the main method of transmission between countries (as a start date of the pandemic suggests a new transmission), but for countries with low tourism, a bundle of endogenous effects, such as geographic location, was the main determinant.

Mexico, located in North America, was the point of origin for the pandemic, and it next moved to the United States (Global Health Atlas). Among countries with high and very high development, countries in North America were the first to report cases of swine flu, followed by Asia and South America. The less developed (medium rating) countries of North America reported cases only after the virus had moved to Asia and South America. Countries of medium development in Africa report the virus around the same time as less developed countries in Asia, while countries in Europe were the last to get swine flu. Visualizations of the distribution of start dates are given in Figure 5 (non-cumulative) and Figure 6 (cumulative).

Temperature hypothetically could have two types of effect on the flu experience. First, warmer countries likely have more tourism, thus serving as a proxy for an increased number of incoming travelers, bringing H1N1 influenza to the country earlier. In addition, colder climates may force people to spend more time indoors, reducing person-to-person transmission. The interactions of temperature and tourism by continent are detailed in Table 7. While warmer countries in Asia experienced less tourism overall, countries in North Africa, Europe, North America, and South America demonstrated a positive relationship between temperature and tourism, supporting the proxy hypothesis.

Looking at the interactions between temperature and tourism, there is no consistent effect across temperature and tourism groupings. However, for a given temperature (excluding those of median temperature), having more tourism correlates with an earlier start date to the pandemic (Table 9).

II. The Pandemic Experience

One would assume that the number of cases in a given week was determined by a combination of factors endogenous to the country and the time, as well as exogenous factors like the previous number of cases. Because influenza is transmitted person-to-person, some existing number of cases is necessary to cause more cases, with the exception of travel's contribution to international disease. Table 1 details the model of each of these factors.

Specifically, the model includes dummy variables for each continent (Oceania excluded), dummy variables for each category of the United Nations Human Development Program Human Development Index (low development omitted, medium development excluded because of collinearity), a one week lagged indicator of new H1N1 cases, time variables for each year-month combination and individual calendar months, and demographic variables for population, gross domestic product, annual tourism counts (2008), and annual reported seasonal influenza cases (types A and B, 2008).

Although the coefficient on the lag of new cases is small, this regressor explains 45% of the variation in "now" weekly cases. Adding in the controls increases the explanatory power of the model to 60%. The positive (and significant) coefficient on the lag of new cases suggests that existing cases will cause new weekly cases, continuing the pandemic in the absence of exogenous influence.

III. Policy Interventions

As soon as the epidemic was announced, countries began to prepare for its arrival—or to attempt to prevent it. Four policies are analyzed in this paper—thermal scanning at airports to detect and quarantine those with elevated body temperatures, restrictions on flights coming from countries with H1N1 influenza, banning the import of pork, and providing vaccines to the general public.

Policy selection varied across levels of development, as seen in Figure 7. More than three quarters of the most developed nations chose to have mass vaccination campaigns, while less than 10% of them chose to enact bans on pork imports. Conversely, while about half of the countries of medium development held vaccination campaigns, 20% banned pork, 25% banned flights, and half of them used thermal imaging cameras at points of entry.

Figure 8 shows how policy selection varied across regions. All countries in Oceania used vaccines and thermal imaging. In Europe, about three quarters of countries held vaccination campaigns, while few supported flight bans, pork bans, or thermal imaging. Countries in Africa were the least likely to vaccinate, with about 30% of countries choosing to do so, while more than 40% installed thermal imaging cameras at points of entry. The only countries to ban the import of pork were located in Europe and Asia, primarily in the Middle East.

Pork import bans and flight bans were the first policies to take effect, as countries implementing these policies instituted them by the fourth week of the epidemic. Thermal scanners were already in place in several countries in Asia because of the SARS and H5N1 pandemics, and other countries adopted them by the eighth week of the epidemic. However, the vaccine was not developed until the fall of 2009, about 28 weeks after the beginning of the epidemic. Some countries did not make the vaccine available for mass distribution until several months later. The average country rated as "Very High" development started its vaccination program at the beginning of November, while the average country with "High" development started its vaccination program at the very end of 2009.

Countries with “Medium” development didn’t begin vaccination until the beginning of January in 2010, two months later than those with “Very High” development (see Table 11 for details).

Table 12 gives the results of the ordinary least squares regression with increasing levels of controls. In column 7, the preferred specification estimates that countries in which vaccination has begun experience approximately 26 fewer H1N1 cases per week than peer nations, significant at the .01 level. All other policies yield positive coefficients, suggesting that these policies actually increase the incidence of swine flu. Whether these coefficients are representative of underlying correlation, or of overconfidence in the policy eroding base prevention techniques (like handwashing) remains to be proved. However, none of these coefficients are significant at the .05 or .01 level. The set of controls and policies in column 7 explain 88% of the variation in weekly swine flu cases.

Tables 13 and 14 detail the results of a similarly structured Poisson regression. Table 13 is a standard Poisson regression with robust standard errors, and table 14 is panel Poisson model (using country and week as panel dimensions). As in the OLS model, we see a statistically significant reductive effect from vaccination, while the other three policies yield positive (significant and insignificant) coefficients.

IV. Comparison of Pandemic and Post-Pandemic Experience

In August of 2010, The United Nations World Health Organization (WHO) declared that the H1N1 pandemic had moved to the post-pandemic period. WHO characterized the post-pandemic period as one in which the H1N1 strain would exhibit seasonal influenza patterns, contrasted with the high infection rates among the young and healthy during traditionally low influenza times of year seen during the pandemic period.

Looking at cases before (April 2009 to August 2010) and after (August 2010 to March 2011) this formal conclusion, we see that most subgroups (by climate, demographic, and geographic controls) experienced roughly a 60% decline in weekly new cases of H1N1 (Table 15). However, countries in Europe experienced a much more shallow decline in weekly cases, dropping 16% (from 65 cases/week to 55 cases/week). Countries in North and South America, by contrast, experienced a more dramatic decline, with countries in North America dropping 88% (from 322 cases/week to 40 cases/week) and countries in South America dropping 98% (from 109 cases/week to 2 cases/week). We also observe a smaller decline in cases among countries with lower populations, dropping 39% (from 24 cases/week to 14 cases/week), but the regional differences are the most profound.

VI. Conclusion

While vaccination appears to be an effective intervention in reducing H1N1 cases, more research is needed to fully disentangle these effects from country-based differences (as noted by the varying implementation dates among countries of different development levels). Future research should also examine policy effects on morbidity—does vaccination only affect weekly infections, or also the severity of those infections? If a measure of a country's "pandemic end" can be developed, it would be useful to compare the lengths of pandemic experienced by different countries and compare that with the policies introduced. It may be that containment policies such thermal scanning and flight bans don't affect weekly caseloads, but do impact the initial date of the pandemic and the length of the pandemic.

This paper also highlights the need for more consistent accounting of international disease. While many countries did consistently report H1N1 cases to the World Health Organization (WHO), biases in the level of reporting and frequency of reporting limit the conclusions that can be drawn from the WHO's data. In the case of future pandemics, this study should be repeated with more consistent and representative data to fully determine the effects of baseline characteristics and policy interventions on pandemic outcomes.

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Tables and Figures

Table 1: Deaths by Respiratory Pandemic	
Pandemic (Year)	**Deaths**
SARS (2003)	916
H1N1 (2009-11)	14,286
H3N2 (1968-9)	1,000,000
H2N2 (1956-8)	2,000,000

Fig. 1: H1N1 Influenza Cases and Deaths

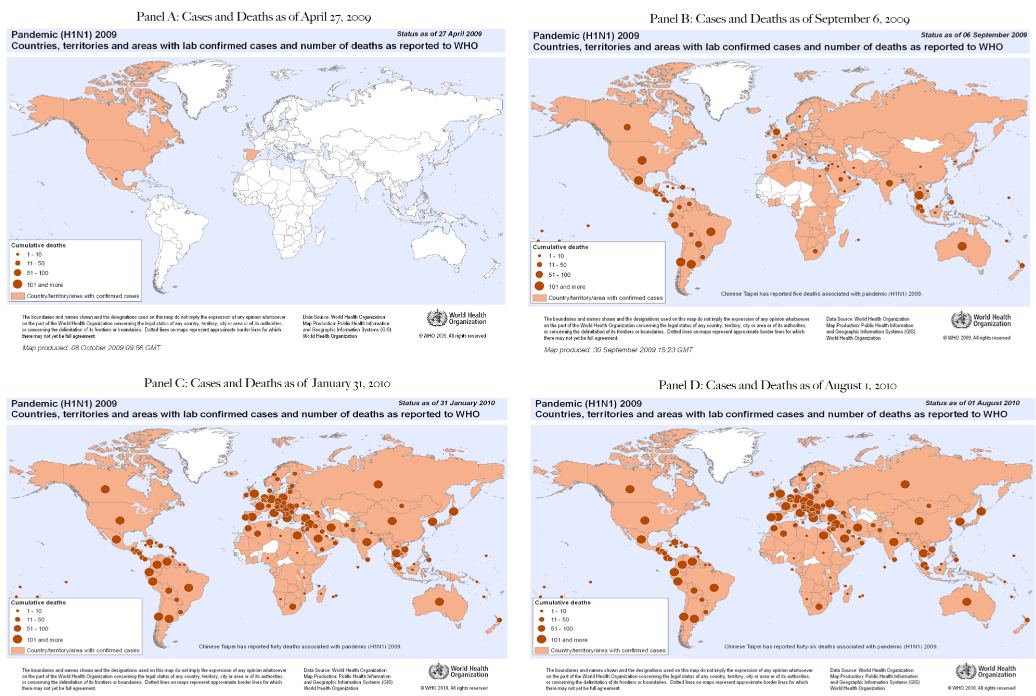


Table 2: Sample Means of Selected Variables		
	Weighted	**Unweighted**
Weekly New Cases	129	--
Population	93,000,000	61,600,000
GDP	71	68.48
Africa	0.13	0.14
Asia	0.22	0.27
Europe	0.36	0.32
North America	0.15	0.13
South America	0.11	0.11
Oceania	0.04	0.03
Very High Development	0.33	0.32
High Development	0.28	0.31
Medium Development	0.36	0.35

Table 3: Mean Weekly New Cases by Temperature and Tourism				
	Less tourism	**to**	**More tourism**	**All**
Cooler	22.56	54.25	153.75	87.76
to	10.47	39.36	331.65	162.38
Warmer	5.71	27	57.1	23.76

Table 4: Mean Weekly New Cases by Policy and Temperature				
	Pork	**Vaccine**	**Flight**	**Thermo**
All	149.37	124.11	144.06	128.81
Cooler	228.84	101.94	250.63	292.44
to	154.2	227.82	126.18	193.96
Warmer	33.28	37.48	29.13	32.95

Table 5: Mean Weekly New Cases by Population and Tourism			
	Lowest Population	**to**	**Highest Population**
All	21.5	49.73	184.33
Less Tourism	12.62	16.96	6.99
to	30.87	33.57	46.85
More Tourism	40.31	123.89	272.67

Table 6: Mean Weekly New Cases by Temperature and Population			
	Lowest Population	**to**	**Highest Population**
All	21.5	49.73	184.33
Cooler	24.79	94.7	203.51
to	37.06	30.77	291.35
Warmer	14.57	9.43	39.12

Fig. 2: Pandemic Start Date by Continent and Development

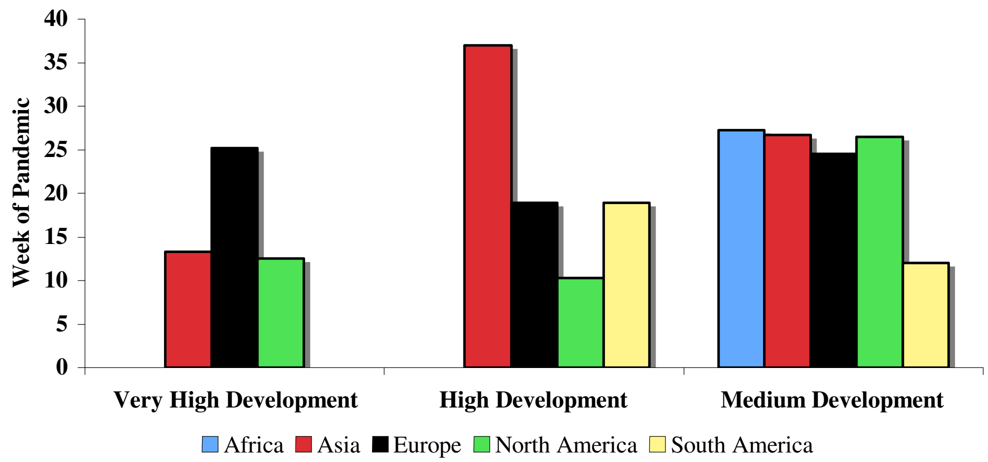
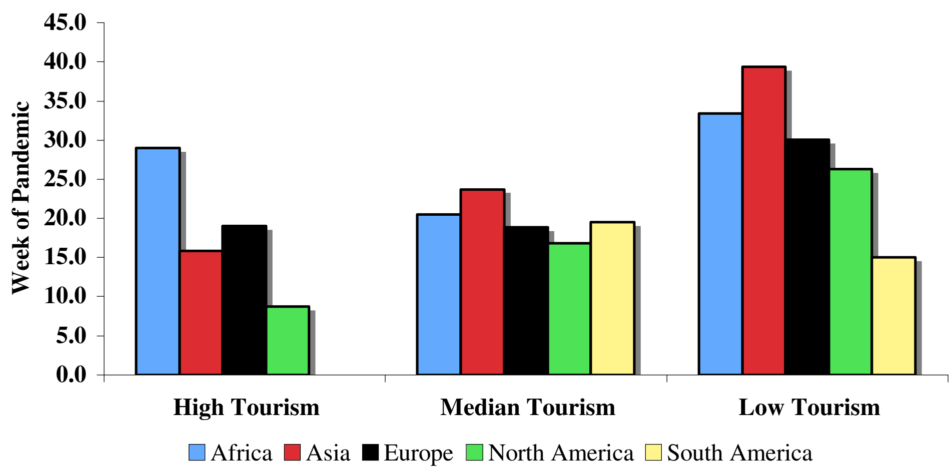


Fig. 3: Pandemic Start Date by Continent and Tourism



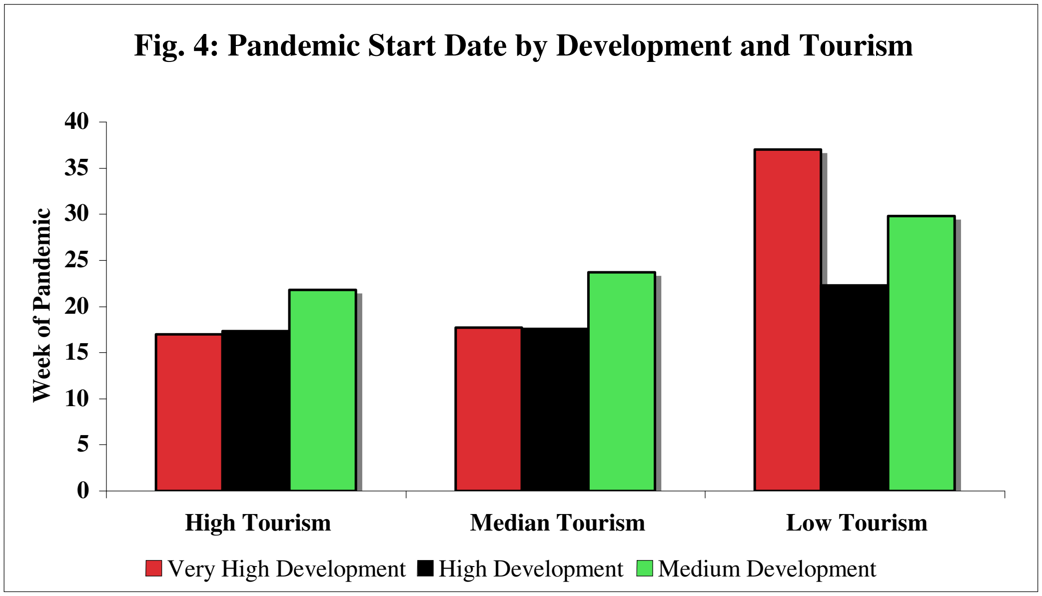


Fig. 4: Pandemic Start Date by Development and Tourism
Week of Pandemic
40
35
30
25
20
15
10
5
0
High Tourism
Median Tourism
Low Tourism
Very High Development
High Development
Medium Development

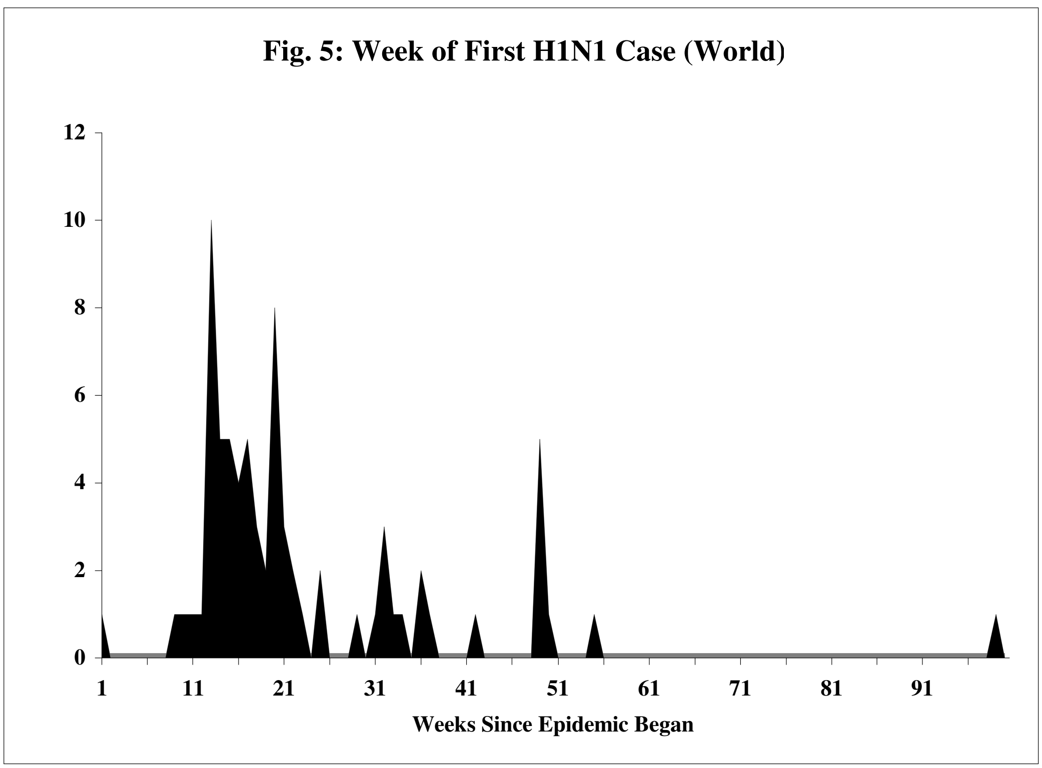


Fig. 5: Week of First H1N1 Case (World)
12
10
8
6
4
2
0
1
11
21
31
41
51
61
71
81
91
Weeks Since Epidemic Began

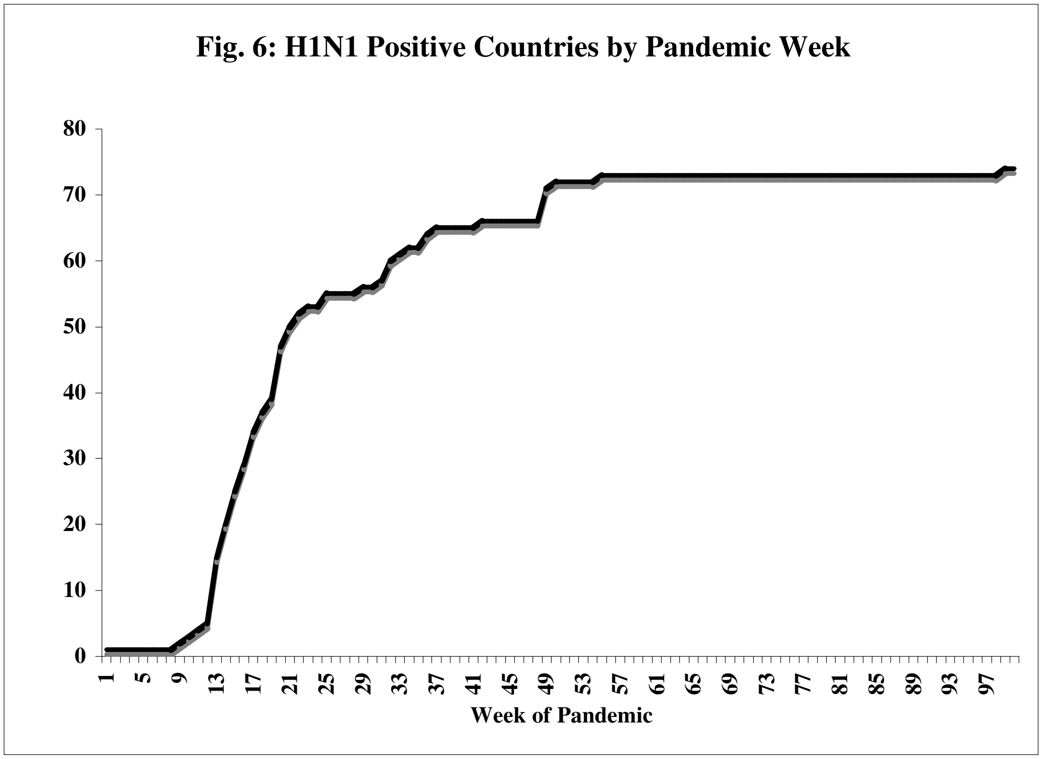


Table 7: Interactions of Temperature and Tourism by Continent (Temperature as Explanatory Variable)

	(1) Asia	(2) Africa	(3) Europe	(4) North America	(5) South America
Temperature	-175.9	176.1	1020.2	177.8	109.8
	(21.8)	(38.)	(53.6)	(45.5)	(7.2)

Table 8: Effect of Development & Tourism on Week of First H1N1 Case

	Medium Development	High Development	Very High Development
Least Tourism	29.8	22.3	37
to	23.7	17.6	17.7
Most Tourism	21.8	17.3	17

Table 9: Effect of Tourism and Temperature on Week of First H1N1 Case

	Least Tourism	to	Most Tourism
Cooler	31.2	18.5	17.5
to	26.6	18.1	19.7
Warmer	31.8	22.7	17.5

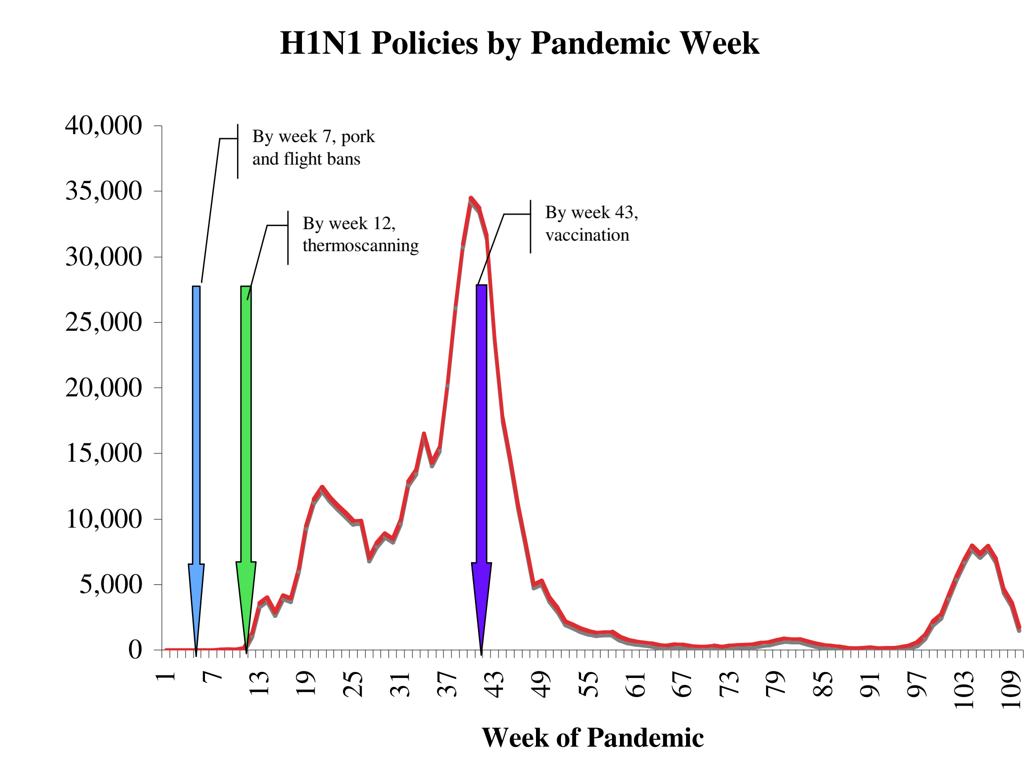


Table 10: Poisson Estimates of Weekly New Cases (Robust SEs)

	(1)	(2)	(3)	(4)
1 Week Lag New Cases	0.00	0.00	0.00	0.00
	(0.00)	(0.00)	(0.00)	(0.00)
Time Controls		Yes	Yes	Yes
Geographic Controls			Yes	Yes
Country Controls				Yes
R^2	0.45	0.51	0.53	0.60

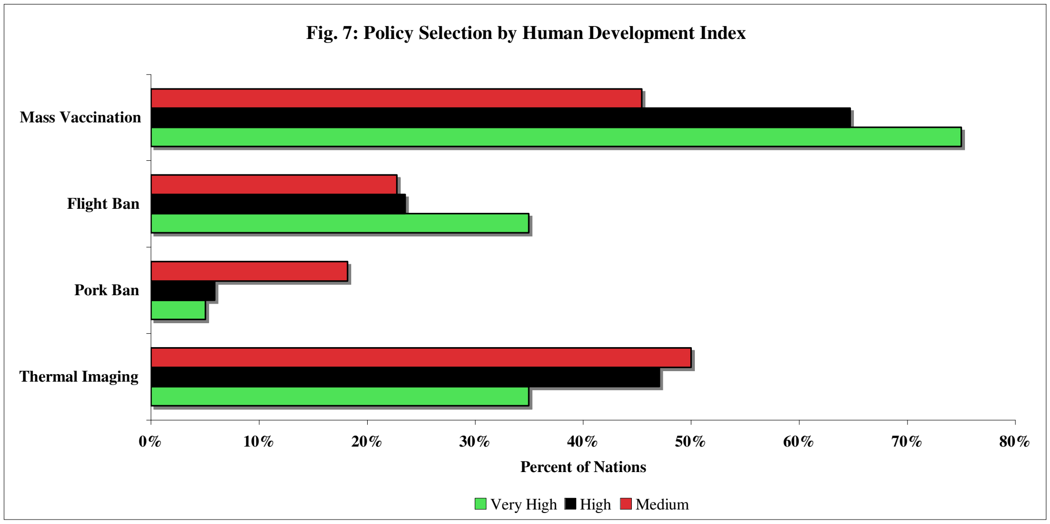


Fig. 7: Policy Selection by Human Development Index
Mass Vaccination
Flight Ban
Pork Ban
Thermal Imaging
0%
10%
20%
30%
40%
50%
60%
70%
80%
Percent of Nations
Very High
High
Medium

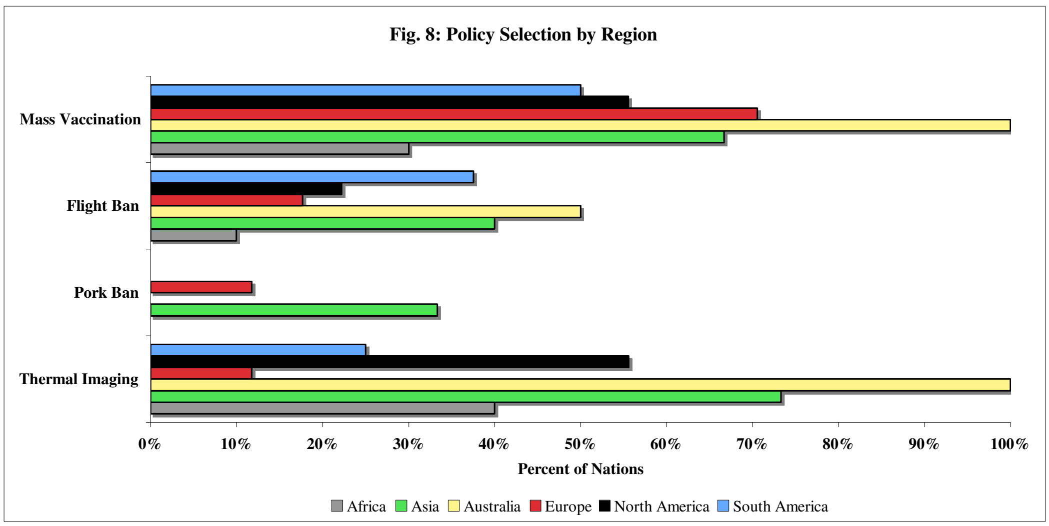


Fig. 8: Policy Selection by Region
Mass Vaccination
Flight Ban
Pork Ban
Thermal Imaging
0%
10%
20%
30%
40%
50%
60%
70%
80%
90%
100%
Percent of Nations
Africa
Asia
Australia
Europe
North America
South America

Table 11: Vaccine Distribution by Human Development			
	Mean Date	Lower Bound	Upper Bound
Very High	8-Nov-09	4-Nov-09	11-Nov-09
High	30-Dec-09	26-Dec-09	3-Jan-10
Medium	6-Jan-10	1-Jan-10	11-Jan-10

Table 12: OLS Estimates of the Effects of All Policies on Weekly New H1N1 Cases (Robust Std. Errors)

Dependent variable is weekly new cases reported to the World Health Organization

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Vaccination Began?	29.11**	-9.88*	-15.61*	-14.75*	-18.27*	-30.21*	-26.42*
	(12.4)	(3.8)	(4.5)	(4.6)	(5.3)	(8.6)	(9.0)
Thermoscanning Began?	60.81*	3.97	4.85	0.87	7.11	12.01	2.40
	(12.3)	(4.4)	(4.7)	(5.5)	(5.5)	(8.9)	(8.7)
Flight Ban Began?	68.67*	5.94	0.44	-1.12	3.42	23.45	13.43
	(14.9)	(6.0)	(6.2)	(6.7)	(8.0)	(8.0)	(7.6)
Pork Ban Began?	69.29*	3.17	3.44	0.26	0.18	18.29	11.68
	(20.9)	(8.2)	(6.5)	(5.9)	(7.8)	(13.3)	(13.1)
1 Week Lagged New Cases		Yes	Yes	Yes	Yes	Yes	Yes
Demographic Controls (Population, GDP, Tourism)			Yes	Yes	Yes	Yes	Yes
Geographic Controls (Continent)				Yes	Yes	Yes	Yes
Influenza Propensity					Yes	Yes	Yes
Country Fixed Effects						Yes	Yes
Week Fixed Effects							Yes
R^2	0.0149	0.8795	0.8800	0.8801	0.8796	0.8801	0.8823
Obs	6431	6230	6163	6163	5184	5184	5184

* Significant at the .01 level
** Significant at the .05 level

Table 13: Poisson Estimates of the Effects of All Policies on Weekly New H1N1 Cases (Robust Std. Errors) Dependent variable is weekly new cases reported to the World Health Organization						
	(1)	(2)	(3)	(4)	(5)	(6)
Vaccination Began?	0.29**	-0.3*	-0.7*	-0.67*	-0.71*	-0.96*
	(.1)	(.1)	(.1)	(.1)	(.1)	(.1)
Thermoscanning Began?	0.60*	0.58*	1.17*	1.15*	1.19*	1.02*
	(.1)	(.1)	(.1)	(.1)	(.1)	(.1)
Flight Ban Began?	0.58*	0.44*	0.12	0.14	0.32**	0.12
	(.1)	(.1)	(.1)	(.1)	(.1)	(.1)
Pork Ban Began?	0.55*	0.5*	0.17	0.24	0.27**	0.12
	(.1)	(.1)	(.2)	(.2)	(.1)	(.1)
1 Week Lagged New Cases		Yes	Yes	Yes	Yes	Yes
Demographic Controls (Population, GDP, Tourism)			Yes	Yes	Yes	Yes
Geographic Controls (Continent)				Yes	Yes	Yes
Influenza Propensity					Yes	Yes
Week Fixed Effects						Yes
Pseudo R^2	0.0631	0.5058	0.5935	0.6021	0.6015	0.6530
Obs	6431	6230	6163	6163	5184	5184

* Significant at the .01 level
** Significant at the .05 level

Table 14: Panel Poisson Estimates of the Effects of All Policies on Weekly New H1N1 Cases Dependent variable is weekly new cases reported to the World Health Organization						
	(1)	(2)	(3)	(4)	(5)	(6)
Vaccination Began?	-0.73*	-0.8*	-0.8*	-0.8*	-0.81*	-1.2*
	(.0)	(.0)	(.0)	(.0)	(.0)	(.0)
Thermoscanning Began?	2.45*	2.1*	2.1*	2.1*	2.19*	1.62*
	(.0)	(.0)	(.0)	(.0)	(.0)	(.0)
Flight Ban Began?	8.21*	7.86*	7.76*	7.68*	7.86*	6.94*
	(.6)	(.5)	(.5)	(.5)	(.6)	(.5)
Pork Ban Began?	7.81*	7.34*	7.15*	7.09*	7.3*	6.08*
	(.8)	(.7)	(.7)	(.7)	(.8)	(.7)
1 Week Lagged New Cases		Yes	Yes	Yes	Yes	Yes
Demographic Controls (Population, GDP, Tourism)			Yes	Yes	Yes	Yes
Geographic Controls (Continent)				Yes	Yes	Yes
Influenza Propensity					Yes	Yes
Week Fixed Effects						Yes
Log likelihood	-722989.48	-425504.04	-423244.92	-423241.68	-409159.06	-345656.98
Obs	6431	6230	6163	6163	5184	5184

* Significant at the .01 level

Table 15: Mean Weekly New Cases During & Post-Pandemic

	Pandemic	Post-Pandemic	% Decline
All	108.55	41.05	-62%
	(7.34)	(4.07)	
Africa	25.06	12.17	-51%
	(3.64)	(3.41)	
Asia	135.19	52.58	-61%
	(15.38)	(10.5)	
Europe	65.27	54.91	-16%
	(5.82)	(7.19)	
North America	321.98	40.22	-88%
	(40.91)	(11.71)	
South America	108.55	1.87	-98%
	(7.34)	(.36)	
Very High Development	164.65	63.82	-61%
	(16.62)	(7.36)	
High Development	101.42	33.86	-67%
	(12.38)	(8.93)	
Medium Development	66.75	27.71	-58%
	(8.59)	(5.83)	
Low Tourism	16.1	6.76	-58%
	(1.53)	(.72)	
Med Tourism	46.54	10.23	-78%
	(4.51)	(1.21)	
High Tourism	246.19	98.16	-60%
	(19.66)	(10.71)	
Low Temperature	103.82	42.2	-59%
	(11.72)	(5.68)	
Med Temperature	191.33	71.53	-63%
	(18.1)	(10.96)	
High Temperature	28.49	9.66	-66%
	(2.53)	(1.85)	
Low GDP	77.67	29.36	-62%
	(9.57)	(6.31)	
Med GDP	78.65	28.07	-64%
	(9.96)	(7.07)	
High GDP	171.07	65.16	-62%
	(17.28)	(7.58)	
Low Population	23.65	14.45	-39%
	(2.15)	(1.6)	
Med Population	60.69	19.03	-69%
	(9.54)	(3.97)	
High Population	220.41	80.04	-64%
	(17.59)	(9.79)	

Honors Summary

The 2009 H1N1 Influenza Pandemic was the basis for many fears, precautions, and policies. This paper seeks to discover the key determinants of each country's pandemic experience—what factors influenced its arrival, its sustenance, and its eventual dissipation. The H1N1 pandemic ended in August of 2010, but the virus still circulates in most of the world as part of the subtype A seasonal influenza. Study of this influenza pandemic may help prepare the world to take multilateral action against the next threat of outbreak.

I built my dataset of policy selections from news articles during the pandemic, checking which of the four policies (vaccination, thermal scanning, pork bans, and flight bans) were used in each of the 88 countries. My weekly H1N1 case data come from the United Nations World Health Organization, and includes weekly reports for 110 weeks, from the spring of 2009 to spring of 2011.

In constructing a model that would predict the weekly caseload of each country I thought about how a pandemic functions. Each country must have a point of contact that brings the virus to the country, as H1N1 influenza is contagious, not environmental. I used international visitor arrival data to construct a measure of tourism, and also included a variable for each continent to account for the increased likelihood of travel between nearby countries.

But travel alone would probably not be enough to determine how long the pandemic would last in a given country. A country's population, level of development, and a range of social factors would seem to determine the likelihood of the disease to spread within its borders. I included population, gross domestic product, and seasonal flu infection rates for each country to account for any baseline variation in susceptibility (like variations in personal space) or in reporting (as seasonal flu cases are reported via the same mechanism). I also included a one-week lag of weekly new cases to account for the contagious nature of the disease—in the absence of travel, one must have old cases to cause new ones. Finally, I adjusted for country-specific trends and week-specific trends by using variables for fixed effects.

These factors gave me a model of predicted pandemic behavior. However, these factors predicted that the pandemic would continue much longer than it did. Adding the policy variables to the model, it appears that mass vaccination campaigns had a significant effect in reducing the average weekly caseload, and given the widespread adoption of this policy, it likely had an effect in speeding the end of the pandemic. The policy variables are coded as "has it happened yet," meaning that the regression model looks at each country-week combination, and compares it with the set of policy dates and countries. For a country that began vaccinating during the 43rd week of the pandemic, all observations (weeks of data from that country) from weeks 44 on will be coded as "yes" (in reality, "1"), allowing the model to generate a coefficient for the effect on weekly cases of being in a week in a country where vaccines have been distributed, compared to a week in that country before the policy was implemented and to weeks in other countries not implementing this policy.

Ordinary Least Squares (OLS) regression works by identifying the *unique effects* of each variable on the regressor of interest, in this case, weekly new cases.

For example, more populous nations may tend to have higher GDPs, causing these two variables to affect new cases in a similar way. OLS kicks out the shared effects, and creates a coefficient based on specifically having the attribute of the variable. The coefficient is the expected change in weekly new cases based on a one-unit change in the variable. As the policies are coded in a binary form, their coefficients are the effects of having the policy in place.

A Poisson regression takes a slightly different approach. This model assumes that the count presented in the dependent variable is a function of independent vectors. My model uses three such vectors—one for a country's baseline characteristics, one for a given week's expected impact (week fixed effects), and one for the policies' expected impact, based on country and on week. The coefficient on a Poisson regression is interpreted as the natural log of the change in weekly cases corresponding with a one-unit difference in the vector predictor. As the policy variables are still coded in a binary form, their coefficients are the effects of having the policy in place, rather than a gradient-like spectrum of effects.

I also used sample means from my data set to determine the effect of various demographic and geographic factors on the arrival of the pandemic in a given country. In general, warmer countries with the most tourism and the highest level of development had the earliest start to the pandemic. However, geographic factors also played a role. Countries in North and South America had the earliest reporting of cases, while countries in Asia and Africa experienced a much later start to the pandemic.

Finally, I was curious about the effects of being in a "post-pandemic" period compared with a pandemic period, and wanted to see if I could find representation of what caused WHO to change its description. While panels C and D of figure 1 provides some insights into the stabilization of the situation, I wanted to numerically compared the April 2009 to August 2010 period with the August 2010 to March 2011 period.

These results are presented in table 15. I found that most subgroups (by climate, demographic, and geographic controls) experienced roughly a 60% decline in weekly new cases of H1N1 (Table 15). However, countries in Europe experienced a much more shallow decline in weekly cases, dropping 16% (from 65 cases/week to 55 cases/week). Countries in North and South America experienced a more dramatic decline, with countries in North America dropping 88% (from 322 cases/week to 40 cases/week) and countries in South America dropping 98% (from 109 cases/week to 2 cases/week).

This may be due to the different start dates among the three continents—North and South America's pandemic may have been nearing an end earlier in 2010 while Europe's later start date may have pushed the height of the pandemic later. However, further research into the "life cycle" of pandemics is required to fully understand these and the policy effects.